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Building Information Modeling (BIM) Implementation for Sustainability Analysis: A Mega Airport Project Case Study

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ABSTRACT
It has been generally perceived that decision-making processes for implementing sustainable solutions to building elements should be in design and pre-construction phases. This perception hinders the transformation of current non-sustainable buildings into sustainable ones. It has been realized that retrofitting existing buildings can be more beneficial in terms of time and cost compared to new construction. This study aims to show that implementation of Building Information Modeling (BIM) for energy analysis improves the retrofit planning process. This study explains that in practice, BIM tools provide significant opportunities for creation of Building Energy Modeling (BEM); and the outputs of BEM analysis can be readily used in selection of energy efficiency measures. The case study approach is used in this study. Accordingly, 3D energy models of the Istanbul Grand Airport Project have been created. A heuristic optimization depicts a clear picture of why it is necessary to incentivize transforming BIM to BEM for decision-making processes of retrofitting. Correspondingly, the study findings show that BIM implementations can provide cost and time savings for energy analysis practices.

KEYWORDS
Building Information Modeling, Building Energy Modeling, retrofitting, heuristic model

INTRODUCTION
Energy analysis tools are integral to the process of identifying and implementing building energy savings measures (Evan, 2003). Such tools have many uses; typically, they are used for design of new building or renovation of existing ones with detailed design analysis (Sanquist & Ryan, 2012; Evan, 2003). Appropriate utilization of building energy analysis tools leads to accurate and cost-effective energy analyses, which depict the total energy use and savings opportunities. The origins of building energy software trace back to the 1970s. Before then, energy analysis was managed by hand at significant cost and time. According to Evan (2003), in the 1980s, the first-generation of simulation-based analysis and design tools emerged. From late 90s until now, rapid proliferation of tools targeted at a broader spectrum of users and the advent of web-based tools. Through web and literature searches, commonly used whole building energy simulation software tools in North America are compiled: TREAT, Sefaira Architecture, EnergyPlus, Pleiades+COMFIE, Autodesk Insight 360, EDAPT, TRNSYS, eQuest, TRACE 700, REM/Design, Open Studio, EDGE Excellence In Design, Design Builder, HA (Carrier).

Moreover, the opportunities can be magnified using recent innovations in energy management tools that provide greater access to energy use data as well as analytics and increased intelligence to optimize systems (Woo & Gleason, 2014). Additionally, typical processes of whole Building Energy Model (BEM) generation are subjective, labor intensive, time intensive, and error prone (O'Donnell, et al., 2013). At this point, it is clear that integrating BIM and BEM generates value in terms of time, cost, and quality since BIM-based building energy models are capable of collecting and also rapidly processing real-time energy performance data. This also provides more accurate and detailed input and output for energy simulation process.

Using the aforementioned energy analysis tools for retrofitting with an optimized investment budget appears to be a viable investment tool. Such procedures can provide substantial savings in terms of energy use, energy cost, and carbon emissions. (Camlibel & Otay, 2011) Not all facility managers, building owners, and other related parties have the ability to access and use a sophisticated optimization software. There are cases in which fast and cost-efficient processes are needed. Heuristic approach can be used to calculate energy, energy cost, and CO_2 savings per invested amount for different energy efficiency measures (EEMs) (retrofit alternatives). Heuristic approach includes the following steps: calculating energy, energy cost, CO_2 savings per investment for each EEM; showing budget amount by drawing a vertical line along the budget amount; selecting EEM with the highest value of saving per USD on the left side of the vertical line; subtracting the selected EEM's investment amount from the given budget; drawing a new vertical line along the new value of the budget amount (Camlibel & Otay, 2011). This process is repeated until the budget no longer supports any other EEM. Thus, the BIM-BEM integration can improve heuristic optimization and selection of energy efficiency measures by providing fast and more accurate input data.

This study shares the energy analysis approach applied to Istanbul Grand Airport Project BIM models. The project encompasses four phases, which includes six runways, three terminals, and an annual 200 million passenger capacity. The first phase of the construction started in 2015. It was planned to make the airport operational in the first half of 2018. This timeline shows that the energy analysis results address the potential future rework that may target to meet or exceed performance guidelines set by building rating systems (e.g., ISI's Envision and the Middle East's ESTIDAMA which include energy efficiency of building envelopes, day-lighting performance, and embodied energy as the crucial part of their evaluation.)

In the literature, it is generally discussed that BIM-based energy modelling utilization leads to sustainable design, and provides easy access to energy analysis results in the early design process. However, to the authors' knowledge, there are no case studies showing that BIM can contribute to sustainability, not only in the design phase, but also throughout the life cycle of the building. Essentially, this study tries to fill the gap in the literature, via proposing BEM generation, by the use of BIM to accelerate the energy retrofitting decision making process.

METHODOLOGY

The case study shows the energy analysis procedure used for Istanbul Grand Airport (IGA) Project BIM models. These models are composed of architectural and structural Revit models. As one of the world's largest aviation projects, the IGA Project encompasses a terminal building with a total floor area of 950,000 m^2, and pier buildings with a total floor area of 320,000 m^2. The methodology used in the case study enables a holistic approach on the magnitude of future energy consumption of IGA project. In this respective order, the methodology contains a selection of the most suitable digital tools, an optimization of BIM models, and generation of an energy analysis.

According to Stumpf, Kim, & Jenicek (2009), the energy modeling process can be divided into two sub-processes. The first sub-process is a macro-level energy analysis, which focuses on comparing building size, shape, and orientation. The second sub-process is a micro-level energy analysis, which considers building details such as wall penetrations and building system details. An energy analysis framework is obtained through the methodology presented below (See Figure 1). It contains data coming from both macro and micro level energy analysis processes.

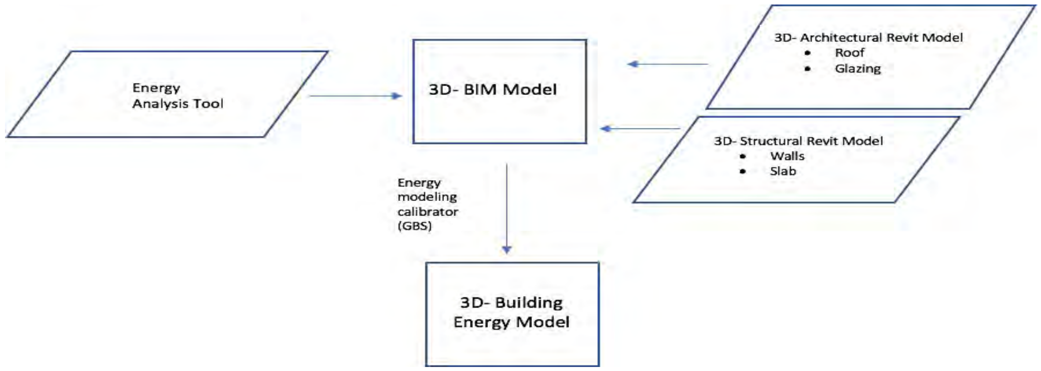

Figure 1: Energy Analysis Process Framework

At the first step of the methodology, the digital tool Insight 360 is chosen for this case study. This tool works as an add-in to Autodesk Revit and integrates existing workflows such as Revit Energy Analysis and Lighting Analysis for Revit. Insight 360 also allows visualization of solar radiation on mass or building element surfaces. Solar analysis includes a new automated workflow for understanding photovoltaic (PV) energy production. Insight 360 also provides a comparison of design scenarios to track performance of the building lifecycle, as well as, measuring the performance against Architecture 2030 and ASHRAE 90.1 benchmarks. The energy analysis results presented in this case study are limited. In essence, only visualization of solar radiation and energy production results are provided.

At the second step, optimization of BIM models, which is mainly dividing and simplifying architectural and structural Revit models, is conducted. Smaller models were extracted out of one master model (See Figure 2). Main purpose of this optimization, which requires discarding some architectural and structural elements, is to achieve the most appropriate model size and complexity for Insight 360, so that the tool can process data smoothly. Such tools have limited capabilities in terms of model size and complexity, making the model shown in Figure 2 infeasible to be analyzed as a whole. Accordingly, five different models with the most basic features (Kim & Anderson, 2011) (See Table 1) were obtained via taking reference of high level zoning plan given in Figure 3. However, it is important to keep in mind that, the number of sub-models should be kept to a minimum. Also, all sub-models should have a fully closed geometry to generate energy analytical models. Overall, the purpose is to eliminate issues including missing elements, elements that are not set to room bounding, gaps in geometry, in-place families, small spaces and surfaces, and columns that cause surfaces to be omitted from the energy model.

Table 1. List of sub-models

Sub-Models
Terminal 1 (all levels)
Terminal 2 + Terminal 3 (all levels)
Pier 1 – Pier 2 (all levels)
Pier 3- Pier 4 (all levels)
Pier 5 (all levels)

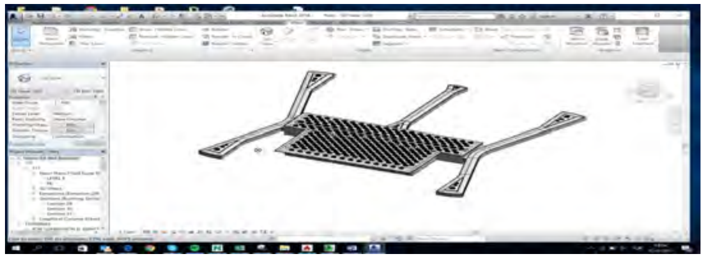

Figure 2: Master Model of the Project

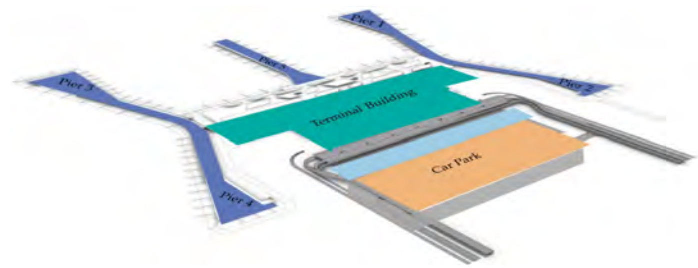

Figure 3: High Level Zoning of the Project

Furthermore, the master model is at its real-world coordinates having high accuracy in level and shape to ensure sustaining maximum accuracy in total volume of energy analytical model. As the third step, energy analysis is conducted; and for that purpose, **Generate** command (in Revit 2017) or **Generate Insight** command (Revit 2016) in **Analyze** ribbon (see Figure 4) is used. The process begins with creation of energy analytical model, followed by transmission of the model to the cloud-based Green Building Studio (GBS) server to obtain the results of energy analysis.

Figure 4: Analyze Command in Revit 2016

RESULTS & DISCUSSIONS

Visualization of solar radiation and energy production results are provided below for each sub-model developed through optimization. The results demonstrate significant total potential in solar energy generation due to the geographic coordinates of the structures, when the retrofitting solutions are applied correctly.

However, the BIM tools used in this study for energy analysis are still under development. Accordingly, it is a significant challenge to optimize models to have accurate flow of data between systems. Since, BIM modeling software market is greatly dominated by only a few companies (e.g. Autodesk Revit), sustainability practitioners are depending upon a limited extend of energy analysis plug-ins; which may otherwise result in compatibility issues.

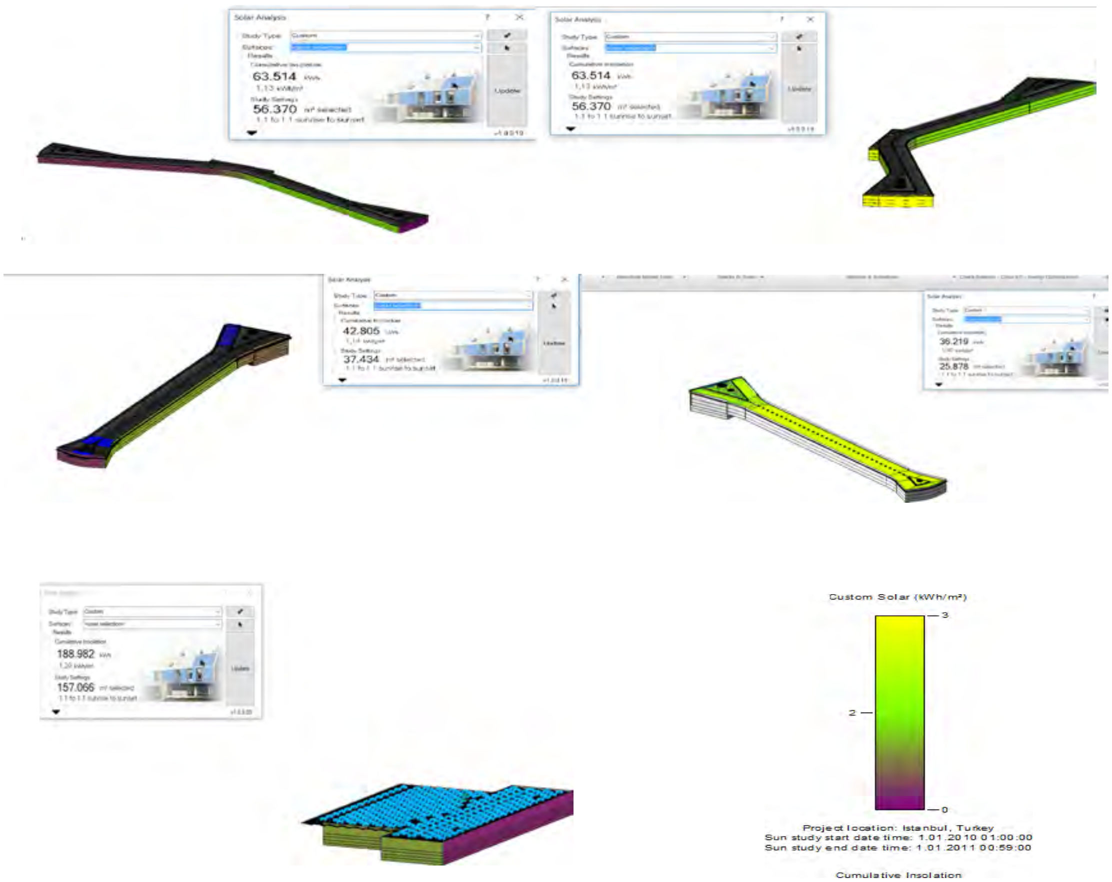

Figure 5: Solar Energy Results for Pier 1-2, Pier 3-4, Pier 5, Pier 5 Roof, Terminal Building, Custom Solar Scale on Energy Units (kWh) per Unit Area (m^2)

Another problem about this BIM application is associated with the lack of guidelines and standardized workflows for right data retrieval from BIM models. Correspondingly, commercial BIM software technology market should further be evolved; and preparation of detailed BIM guidelines should be encouraged to improve the effectiveness of building retrofitting plans.

Retrofitting of existing buildings, as an evolving field of research, represents vast possibilities in increasing the energy efficiency of buildings. Façade design plays a crucial role in the retrofit of a building, and can offer additional benefits by incorporating possibilities of energy production (Bigaila, Hachem-Vermette, El-Sayed, & Athienitis, 2016).

Correspondingly, building-integrated photovoltaic (BIPV) glazing can be suggested as a retrofit solution for this case study. This is a new approach in which PV modules are integrated into the building envelope materials and components. As such, the PV system is not an added component, but rather a part of the essential building envelope. The electricity generated by the BIPV system can be stored in batteries so that the system can be used as an off-grid system. Alternatively, the system can be interfaced with the utility grid and the electricity generated can be sold back to the grid (Verboon & Laufs, 2013).

BIM implementation in the project gives many opportunities in terms of providing easy access to all project data (or one can say "big data") – including 3D models at various levels of detail (LODs), 2D drawings, and all supplemental documents- from a single digital platform. Besides, BIM also allows fast modification or update on data whenever needed while greatly eliminating waste in terms of time and money. As a summary, following points can be listed as benefits of BIM for sustainability;

- Energy modeling (detailed analysis of energy needs of the structure and analysis of renewable energy options such as solar energy),
- Building orientation (providing best building orientation option that leads to minimum energy cost),
- Reducing wasted time and resources for energy analysis (allowing rapid modifications in many design parameters),
- Access to current data for unit energy costs and weather via an internet server.

CONCLUSIONS

Building energy modeling tools provide an efficient, simple method in predicting the energy use of new and existing buildings. Via a decent optimization procedure and project defaults assumptions, energy analysis of all Terminal and Pier Buildings are conducted. Consequently, Autodesk Insight 360 provides annual and monthly data – both in energy units and in monetary units- of total energy consumption of the analyzed buildings. Annual and monthly monetary and energy equivalents of space heating, space cooling, area lighting, hot water supplies can also be generated graphically, which can enable the users to foresee energy consumption levels of airport buildings in future studies. However, in the context of this paper, solar analysis results are presented to articulate the simplicity in extracting data for retrofitting decision-making process. Since the tool aids in conducting iterative process by means of fast data-input, the facility owners can acknowledge the potential in PV energy production at the operational stage of the airport.

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